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Hybrid piezoelectric and biodegradable polymer-based scaffolds for biomedical applications

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There is a growing interest in piezoelectric materials due to their potential of providing electrical stimulation to cells to promote repair of the damaged tissues without external energy source used. A recent study has shown that the most significant effect on fibroblasts has been revealed in case of scaffolds with the largest piezoelectric constants such as polyvinylidene fluoride [1]. Polyhydroxybutyrate (PHB) is biodegradable and piezoelectric polymer [2]. However, PHB possesses reduced piezoelectric properties compared with PVDF. Polyaniline (PANi) is conductive biocompatible polymer and increase piezocharge constants of piezoelectric materials [2]. To the best of our knowledge, the piezoelectric PHB-based scaffolds with PANi are lack studied. Thus, the present study is aimed to fabricate and investigate piezoelectric properties, chemical and phase compositions of hybrid biodegradable scaffolds based on piezoelectric PHB and conductive PANi polymers.

Polymer scaffolds were fabricated using electrospinning. PHB was dissolved in chloroform with PANi mixed as follows: pure PHB (100-0), PHB-1%PANi (99-1), PHB-2%PANi (98-2), PHB-3%PANi (97-3) [2].

The morphology of the scaffolds was characterized by scanning electron microscopy (SEM). Fourier transform infrared spectroscopy (FTIR) spectra were recorded using a Nicolet 5700 FT-IR Spectrometer (Thermo Electron Corporation, USA). To study the phase composition and structure, X-ray diffraction was used (XRD-6000, Shimadzu, Japan) with Cu Kα radiation (λ = 0.154 nm) in the 2θ range from 5° to 90° with a step size of 0.02°/2θ at 40 kV and 30 mA. The piezoelectric charge coefficient (d_{33}) of the prepared scaffolds was tasted using a Wide-Range d_{33} Tester Meter. Surface electric potential of the scaffolds was measured under mechanical loading using a custom-made set contained: two electrodes, oscilloscope and power amplifier (Fig. 1).

Figure 2a represents FTIR spectra of PHB and PHB-PANi scaffolds. PHB-3%PANi spectrum exhibited new bands at ~1603 and ~1589 cm^{-1} (an insert in Fig. 2a) attributed to the aromatic ring [3] and C=N stretching of the quinoid diimine unit correspond to PANi, respectively [4]. At the same time, XRD analysis confirmed the presence of the PANi in the structure. Besides, SEM analysis showed the decrease of the average fiber diameter at the increase of PANi mass fraction in PHB [2]. Finally, it can be seen that the trend was the same for d_{33} and surface electric potential (Fig. 2b), i.e. the maximum of the d_{33} and surface electric potential were observed at the 2%PANi mass fraction in the scaffolds [2].

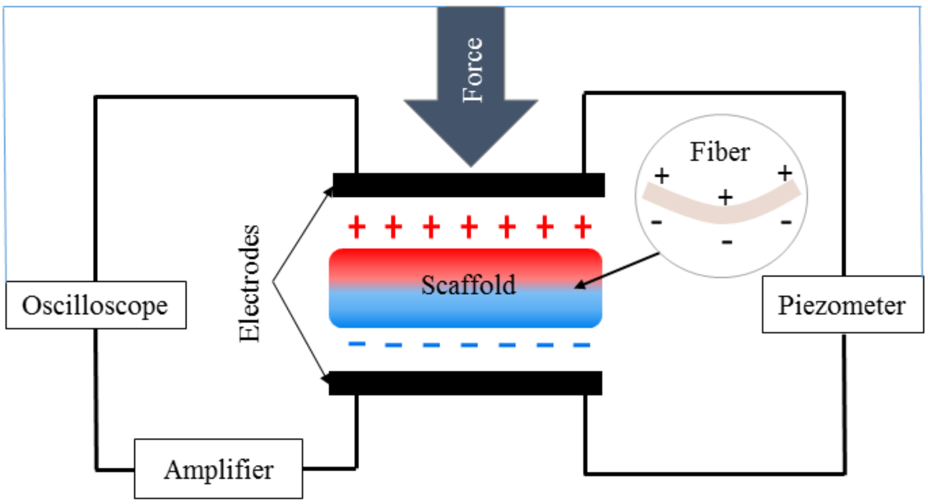

Figure 1. Schematic illustration of the measurements of d_{33} and surface potential.

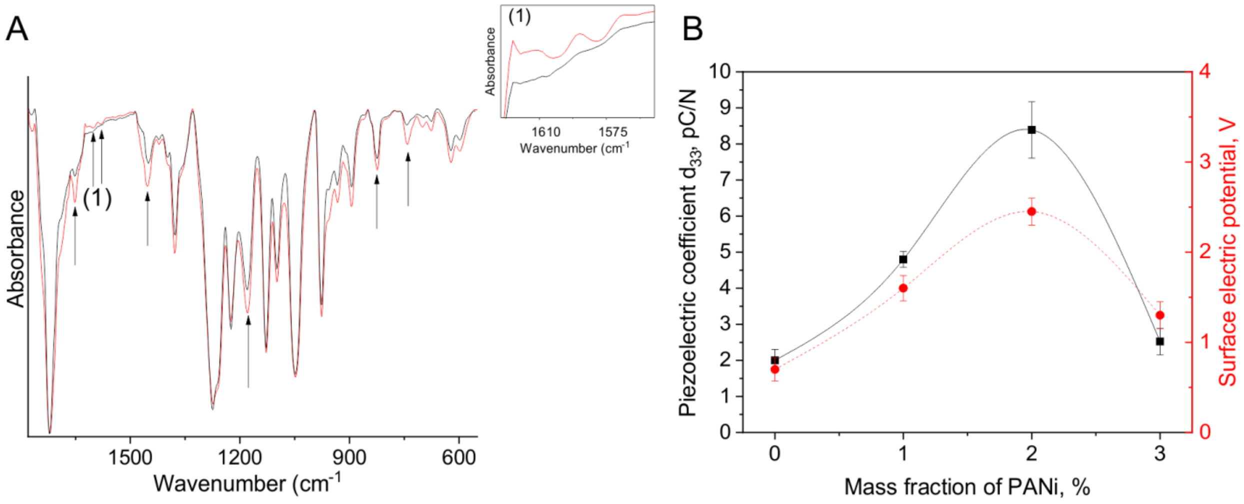

Figure 2. (a) FTIR spectra of the pristine PHB (black) and PHB-3%PANi (red) scaffolds;
(b) The dependence of the piezoelectric coefficient/surface potential on PANi content in PHB.

Fibrous scaffolds based on PHB and PANi can be successfully fabricated via electrospinning technique. Doping of PANi leads to decreasing of the average fibers diameter as well as significantly increased the piezoelectric charge coefficient and surface electric potential of PHB scaffolds. The maximum increase of the piezoelectric coefficient and surface electric potential was observed at the PANi mass fraction of 2%. Thus, the results of the present study can be successfully applied to fabricate a hybrid biodegradable material with improved piezoelectric properties for regenerative medicine.

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